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INDUSTRIAL STRENGTH NETWORKS™

Perspectives and priorities on RuggedCom Smart Grid Research - IEC 61850 Technologies - Jim McGhee

July 23, 2010

RUGGED GRID™
Making the Smart Grid RUGGED™

v1

“Communications is key enabler to Smart Grid”

- Richard Bertolo Smart Grid Project Director Hydro One Networks Inc. May 25, 2010 UTC 2010 Indianapolis

Agenda

- Issues / Research IEC 61850 Process Bus
  - Highly accurate time – IEEE 1588
  - IEC 62439 High Availability Automation Networks
    - PRP - Parallel Redundancy Protocol
    - HSR - High-availability Seamless Ring
  - Simplify Configuration – GMRP (Generic Attribute Registration Protocol)
- Performance requirements IEC 61850 over WiMAX

Reference

- This discussion is based on experience from:
  - Dalv 110kV Substation – Newly Built Installation in China
    - Which detail findings are described in the paper “Practical Experience with IEEE 1588 High Precision Time Synchronization in Electrical Substation based on IEC 61850 Process Bus” being presented next week at the IEEE PES meetings in Minneapolis.
      - This paper describes the experience from the world first installation of High Voltage substation with IEC 61850 Process Bus where IEEE 1588 Time Synchronization and dynamic multicast filtering have been used.
  - RuggedCom and Siemens Energy Collaborate to Deliver Wireless Integrated Smart Grid Applications for Distribution Feeder Automation
    - Solution combines RuggedCom’s wide area wireless solution, RuggedMAX™, with SIPROTEC® compact relays from Siemens

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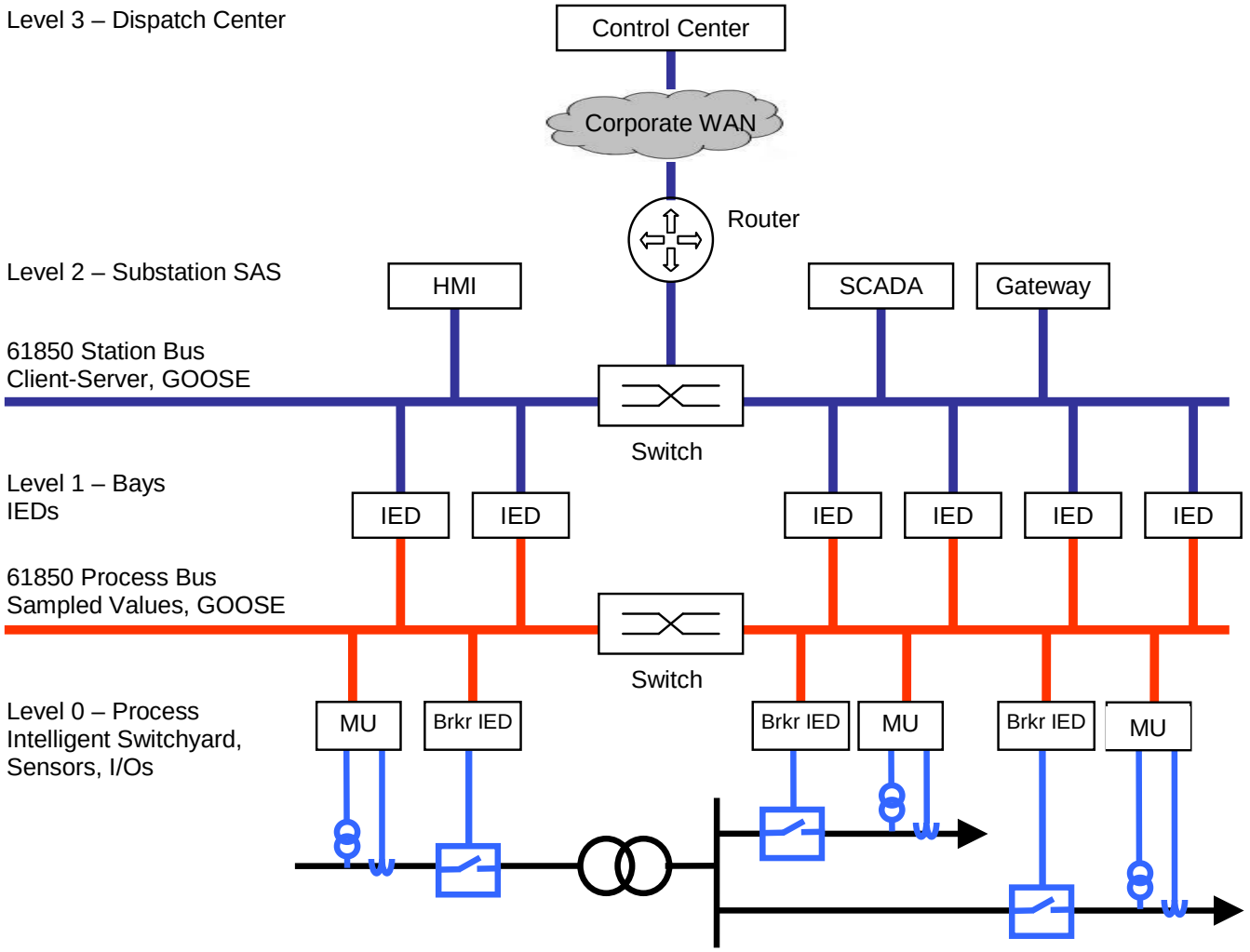
IEC 61850 Station Bus and Process Bus



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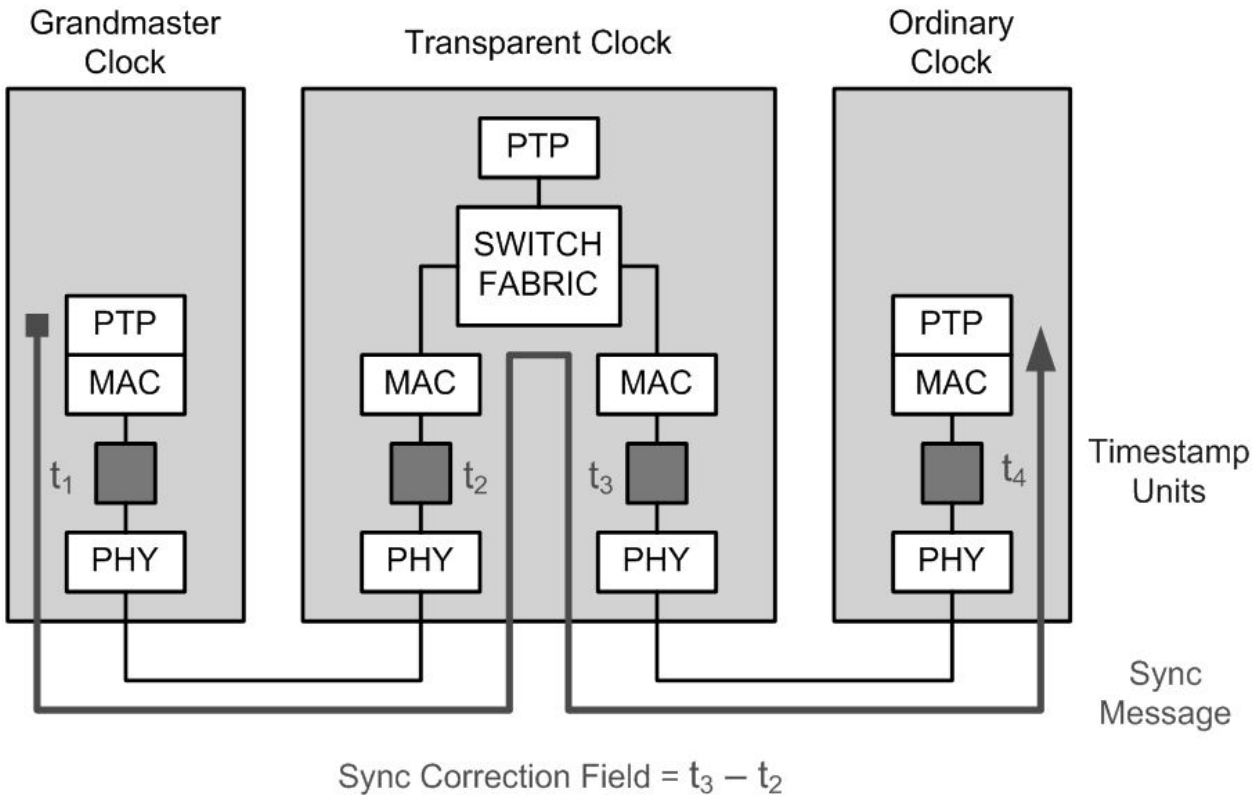
IEEE 1588 Time Synchronization

- IEEE 1588 version II Time Synchronization that has been officially released as standard in mid 2009
- It eliminates the extra cabling requirements of 1PPS or IRIG-B to propagate highly accurate timing signals
- However IEEE 1588 differs from SNTP in one important aspect that allows for hardware assisted time stamping
- IEEE 1588 defines four types of clocks in a PTP (Precision Time Protocol) system: ordinary, grandmaster, boundary, and transparent
- A PTP domain contains only one grandmaster at any given time; redundancy of the grandmaster can be accomplished via the best master clock (BMC) algorithm

IEEE 1588 Time Synchronization

IEEE 1588 hardware assistance is placed between the PHY and MAC layer of an Ethernet device



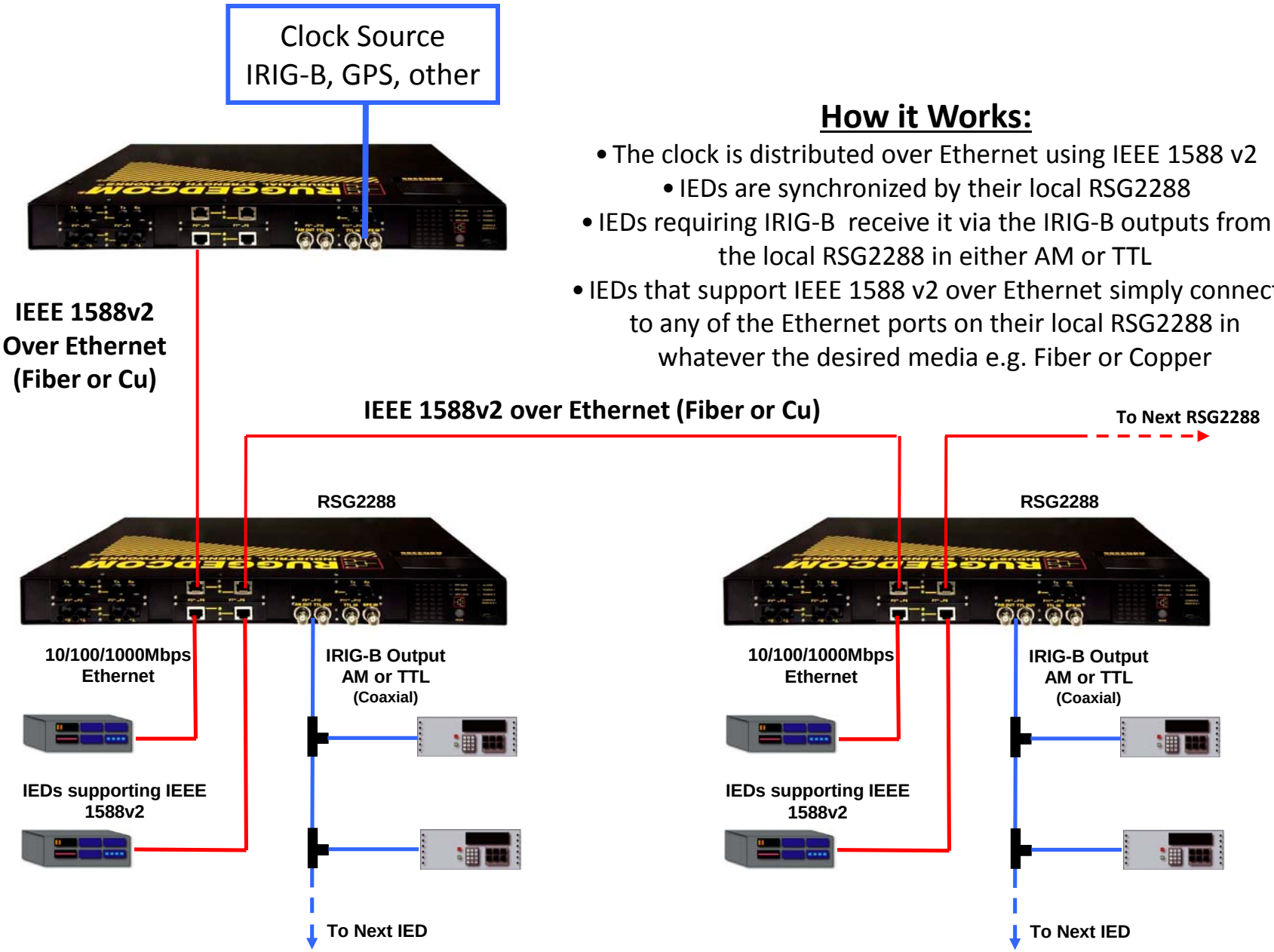
Problems Addressed by IEEE 1588

- Path delay - how long it takes a message to propagate from the grandmaster to the slave
- Many delays are introduced on the path including:
  - Cable delay
  - Encoding and decoding of symbols on the wire
  - Switch fabric latency
  - Store and forward of switches
  - Queuing from switches

IEEE 1588 – Work to be done

- Incorporation into IEC 61850
  - Adding flags to indicate:
    - Clock Source
    - Clock available / accuracy
- More IED vendors need to support native IEEE 1588
- Lack of testing equipment supporting IEEE 1588 protocol
- Large Ethernet chip providers need to supply high quality chips supporting IEEE 1588 – Low Cost

Clock distribution via Ethernet



How it Works:

- The clock is distributed over Ethernet using IEEE 1588 v2
- IEDs are synchronized by their local RSG2288
- IEDs requiring IRIG-B receive it via the IRIG-B outputs from the local RSG2288 in either AM or TTL
- IEDs that support IEEE 1588 v2 over Ethernet simply connect to any of the Ethernet ports on their local RSG2288 in whatever the desired media e.g. Fiber or Copper

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High Availability Networks

- Industrial communication networks: IEC 62439 high availability automation networks
  - MRP – Media Redundancy Protocol based on a ring topology
  - PRP – Parallel Redundancy Protocol
  - CRP – Cross-network Redundancy Protocol
  - BRP – Beacon redundancy protocol
  - DRP – Distributed Redundancy Protocol
  - HSR – Highly Available Seamless Automation Ring
- Rapid Spanning Tree (IEEE 802.1W) RSTP
  - Recovery times: fast < 50 ms, slow up to 2 seconds
  - Ring size limited to 40 switches
  - Recovery time can be deterministic in ring topology, non deterministic in mesh topology

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Supported by IEC 61850

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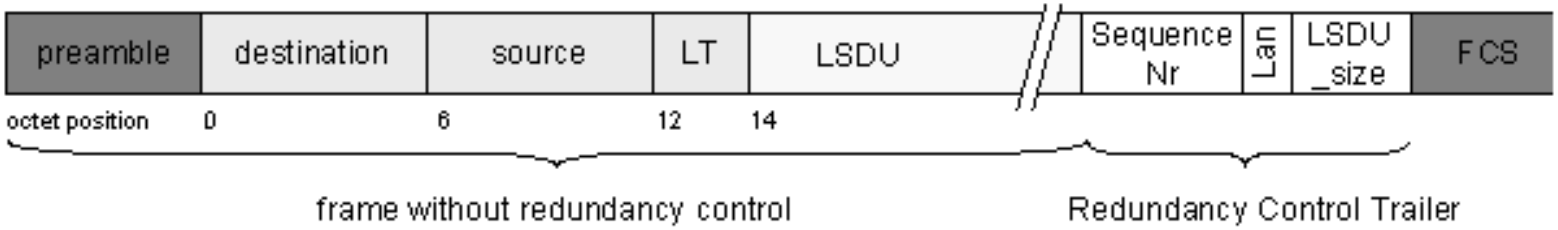
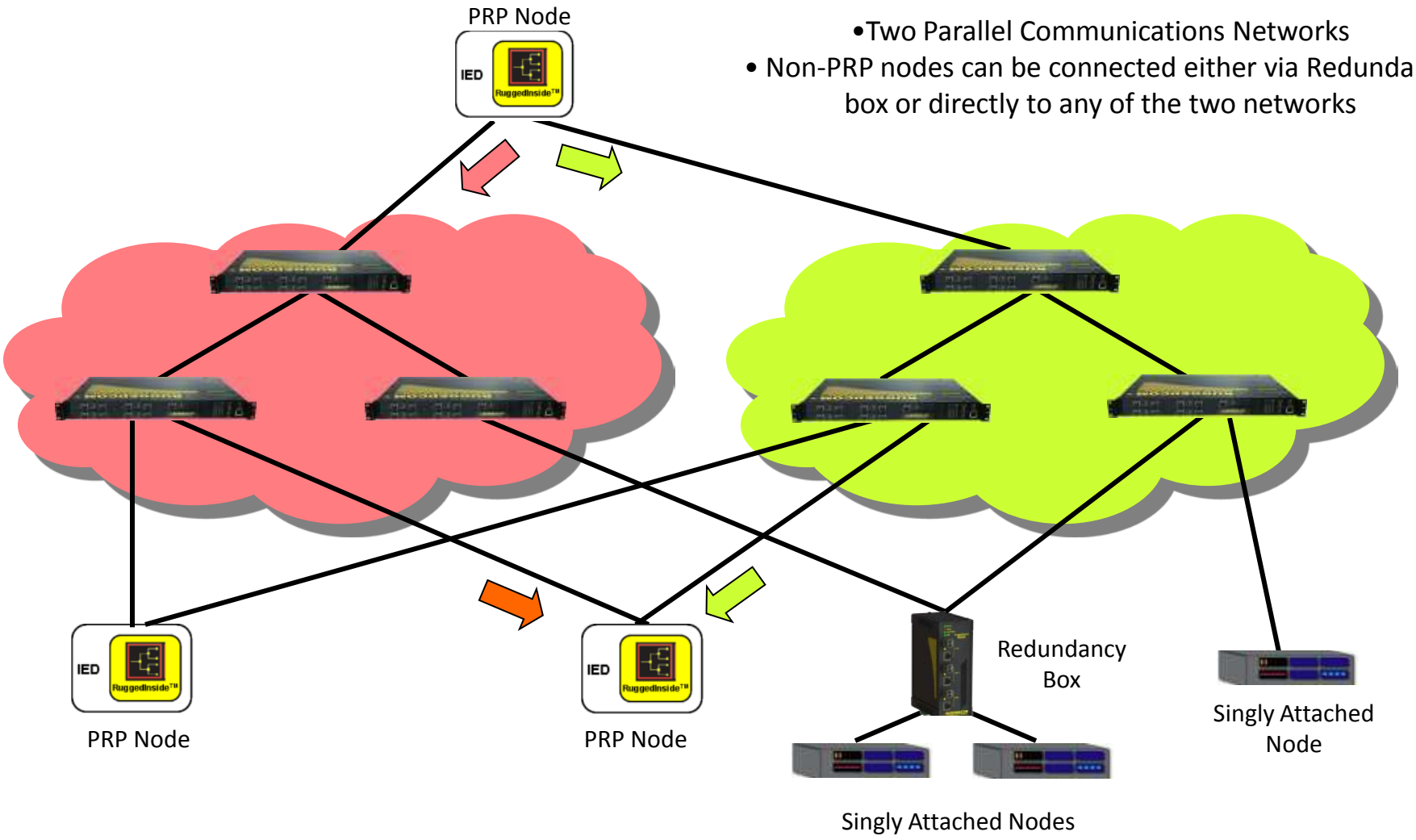
Parallel Redundancy Protocol (PRP)

- Defined in IEC 62439
- Zero-delay packet delivery (“bumpless”) on single point of failure in network
- Uses two independent Ethernet LANs
- End devices are dual homed on each LAN
- Packets duplicated on both LANs
- Duplicate packets eliminated before delivery
- Ethernet frame augmented while in LAN
- Transparent to upper layer, application protocols
- Can be implemented in software



PRP Network Diagram



PRP – Pros / Cons

- Pros
  - Zero time recovery in case of network failure
  - Guaranteed behavior under failure conditions
  - Reduced network engineering costs – static redundancy
  - Reduction in network outages - reduced cost
  - Ability to trust Ethernet
  - Reduction in risk of implementing new protection / control technologies
  - Reduced cost by converging critical and non-critical networks onto a single network
  - Can be implemented in Software
- Cons
  - Double the number of switches over non-redundant systems
  - Redundancy control at end of message – process message prior to determining if duplicated

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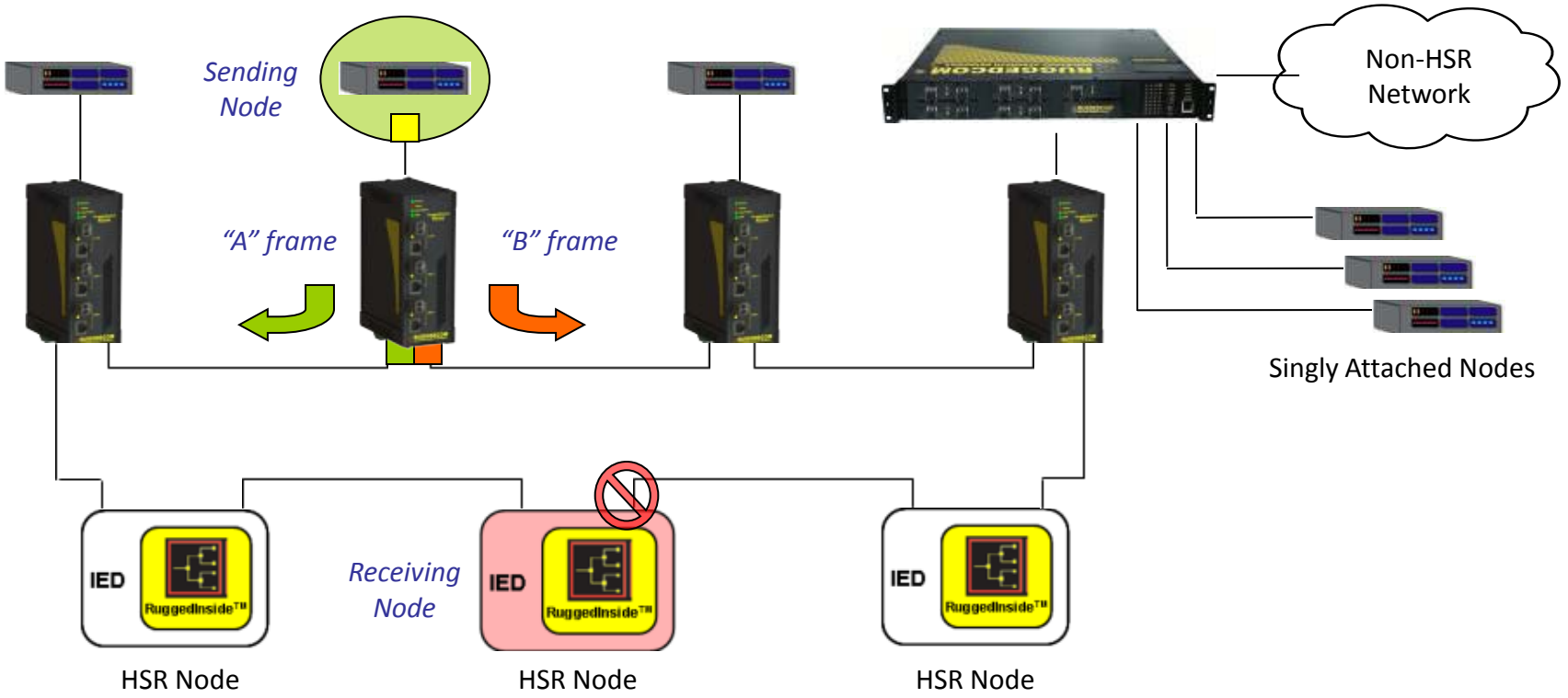
High Availability Seamless Ring (HSR)

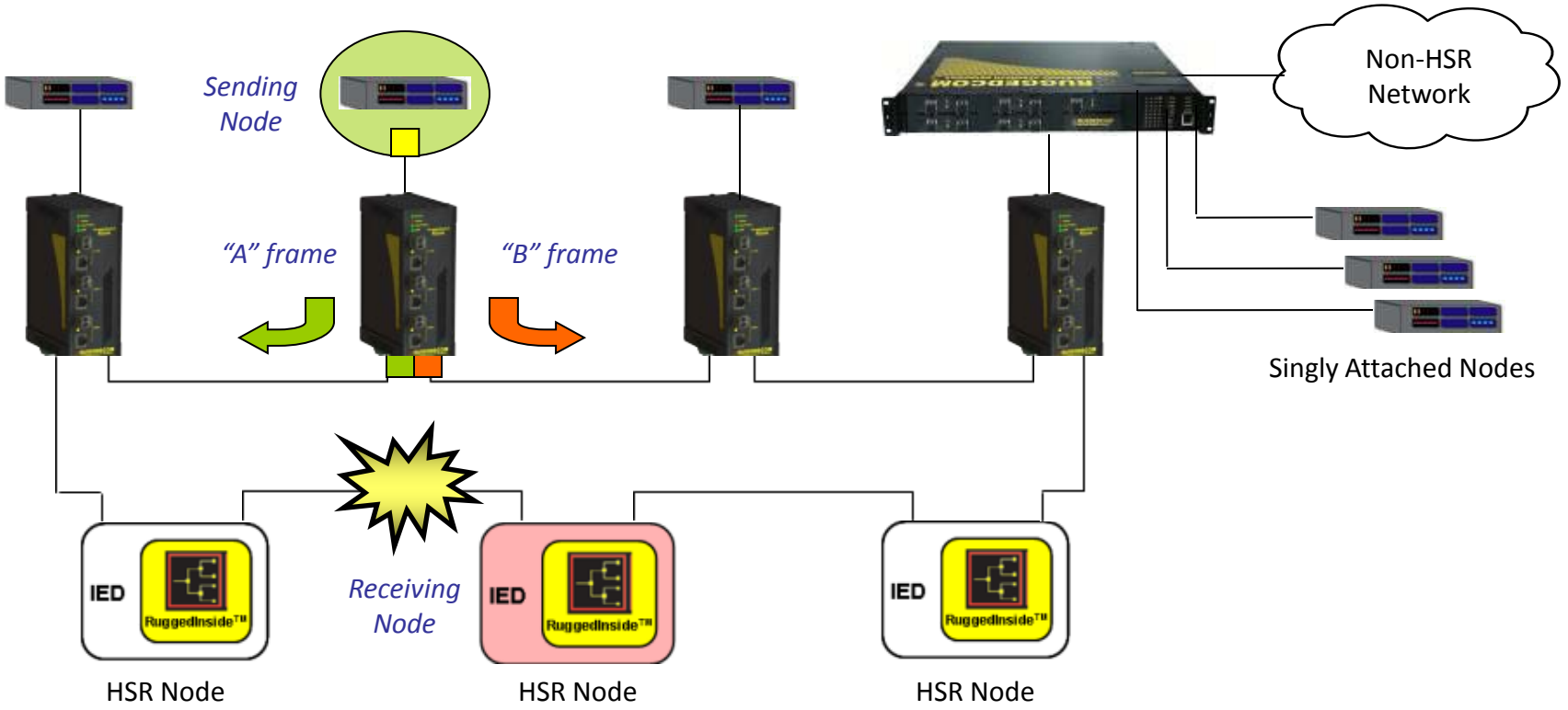
- Defined in upcoming IEC 62439 addendum
- Guaranteed packet delivery (“bumpless”) on single point of failure in network
- Ring topology – can interconnect rings
- Egress packets duplicated in both directions
- Duplicate packets eliminated before delivery
- Ethernet frame augmented while on ring
- Invisible to upper layer / application protocols
- Must be implemented in hardware switches

How HSR Works in Steady State



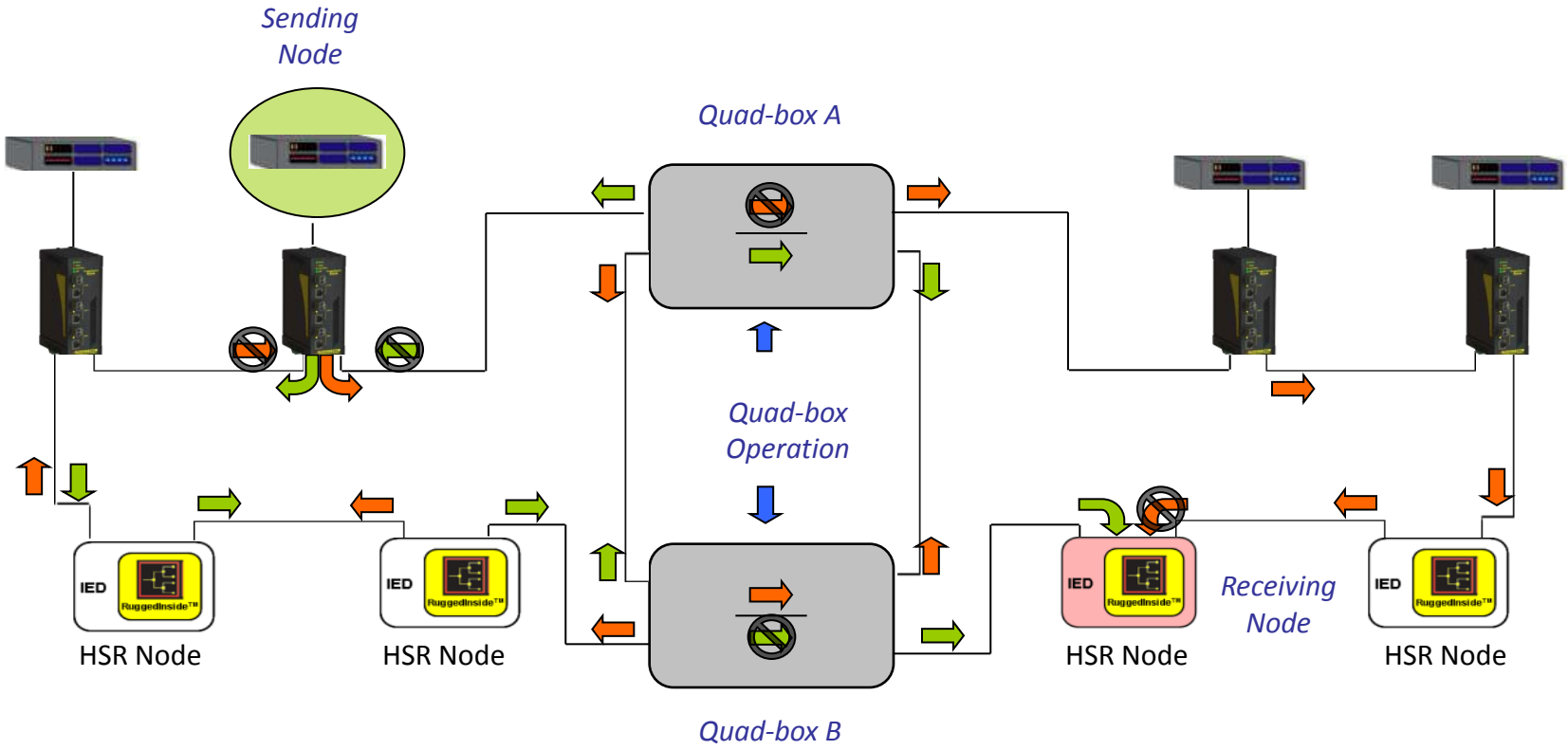
- Duplicate frames sent in opposite directions
- Frames are moved through the HSR network with minimal latency
- Duplicate frames are removed from network by the receiving node

How HSR Works After Link Failure



- In case of link failure the frame still makes it through to the receiving node from the opposite direction
- no data loss and no delay in case of network failure

Coupling HSR Rings with Quadboxes



- HSR is not limited to a single ring architecture
- With "Quad-box" mode of operation, multiple inter-ring communications can be set-up to increase the scale of the network and maintain complete redundancy.

HSR – Pros / Cons

- Pros
  - Reduce number of devices – elimination of switches
  - Zero time recovery in case of network failure
  - Guaranteed behavior under failure conditions
  - Reduced network engineering costs – static redundancy
  - Reduction in network outages - reduced cost
  - Ability to trust Ethernet
  - Reduction in risk of implementing new protection / control technologies
  - Reduced cost by converging critical and non-critical networks onto a single network
  - Best implemented in hardware
- Cons
  - All traffic must go through each device
    - Koichi Hamamatsu, Chief Specialist (Substation Automation System), Energy Automation Systems Engineering Department, Toshiba Corporation – Presented paper at theTC57WG10 June 14-18, 2010 meetings raising concerns regarding bandwidth of HSR systems in very large substations with Bus Differential protection in place. System needed more than 1Gbit Ethernet.

PRP/HSR – Research

- Need vendors to support PRP and/or HSR
- Need to have end customer active participation in pilot project / field trials

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Multicast Management

- Multicast management can be done in a static or dynamic way:
  - Static management is done by creating in all networking devices tables with multicast group addresses and to which ports a specific group address shall be forwarded
  - Multicast filters are created dynamically in Ethernet switches based on the GMRP requests from IEDs that want to subscribe to particular Sampled Values or GOOSE application
- Multicast management must be done at layer 2 (MAC) because GOOSE and SMV are layer 2 protocols
- Need IED manufactures to support GMRP

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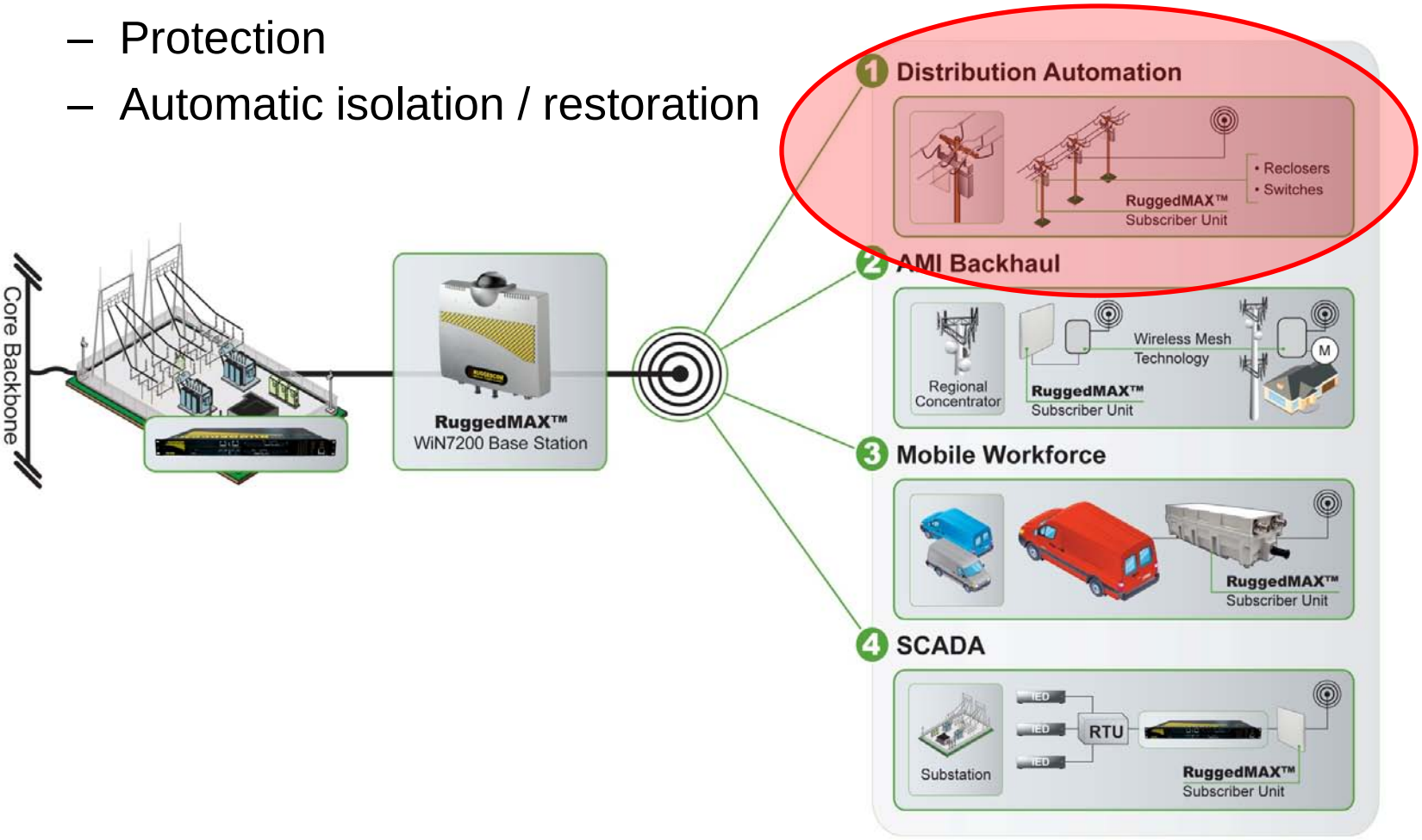
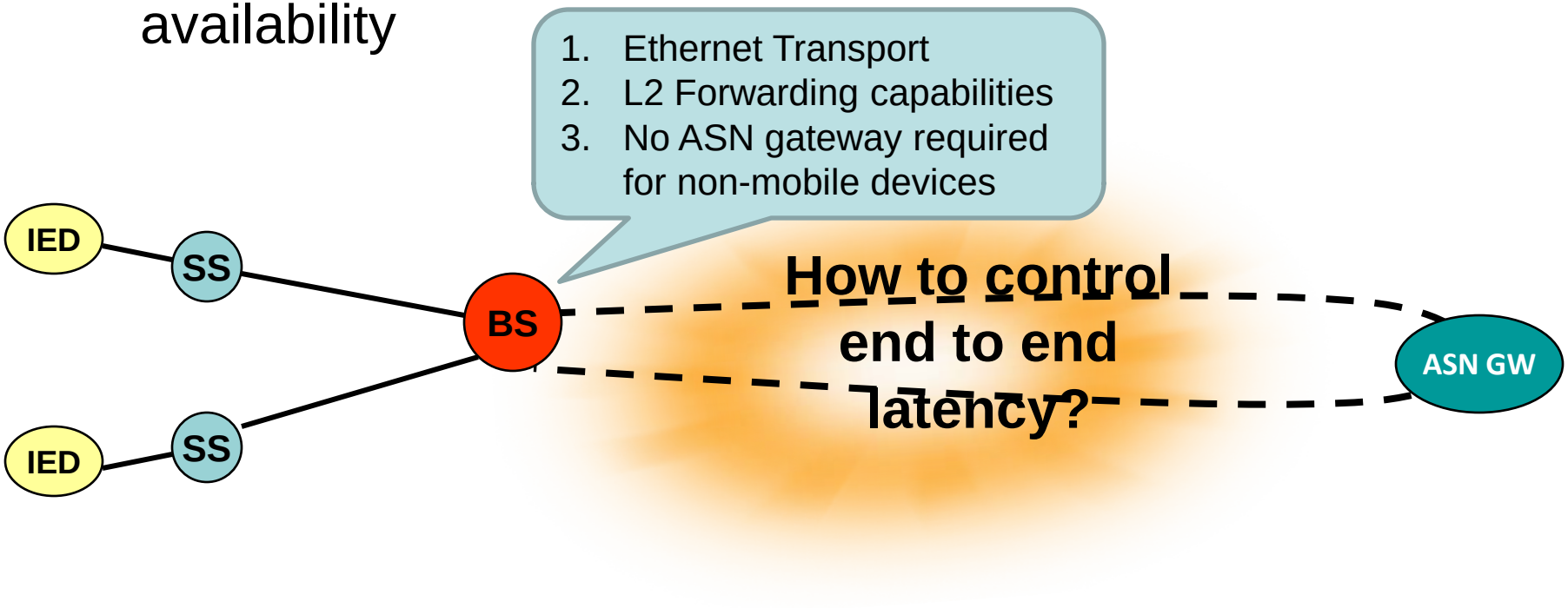
WiMAX System

1. Distribution Automation Applications
   - Protection
   - Automatic isolation / restoration



Network Architecture

- Typical WiMAX network will map all traffic in to a GRE tunnel back to an ASN gateway in the network
  - This is even required if two devices are talking to each other within the same sector
- L2 multicast like GOOSE messages are dropped
- Difficult to predict and control end to end latency and availability



What else do we need to consider?

- What is the performance of the communication network?

4 milliseconds
IEC 61850 GOOSE

1 minute
SAIDI

Where do we need to be?

- <30 seconds?
- <100 milliseconds?
- *Sub-cycle?*

Yes?

Thank You!

If you want a copy of this presentation or the paper "Practical Experience with IEEE 1588 High Precision Time Synchronization in Electrical Substation based on IEC 61850 Process Bus" please email me at:
jimmcghee@ruggedcom.com